COST OF TONNAGE OXYGEN

By Sidney Katell and John H. Faber

* * * * * * * * * * * information circular 7939

March 3, 1849

UNITED STATES DEPARTMENT OF THE INTERIOR
Fred A. Seaton, Secretary

BUREAU OF MINES
Marling J. Ankeny, Director

UNITED STATES DEPARTMENT OF THE INTERIOR
Fred A. Seaton, Secretary

BUREAU OF MINES
Marling J. Ankeny, Director

This publication has been cataloged as follows:

Katell, Sidney.
Cost of tonnage oxygen, by Sidney Katell and John H. Faber. [Washington] U.S. Dept. of the Interior. Bureau of Mines [1960].

6 p. illus., tables. 26 cm. (U.S. Bureau of Mines. Information circular 7939)
Bibliographical footnotes.

1. Oxygen—Industrial applications. 2. Oxygen—Costs. I. Faber, John H., joint author. II. Title. (Series)

TN23.U71 no. 7939 622.06173

U.S. Dept. of the Int. Library

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. - Price 15 cents

CONTENTS

Page

Summary and conclusions.............................. 1

Introduction.. 1

Discussion of results................................. 3

ILLUSTRATIONS

Fig.

1. Low-pressure cycle (discharge pressure, 0.5 to 5 p.s.i.g.).. 2

2. Split cycle (discharge pressure, 450 p.s.i.g.)........ 2

3. Oxygen plant; capital investment vs. daily production. 3

4. Power requirements for tonnage oxygen plants; daily production vs. power requirements.................. 4

5. Oxygen plant; operating cost vs. daily production..... 4

6. Oxygen plant; selling price vs. daily production (return on investment, 12 percent)................. 5

TABLES

1. Estimated operating cost of 500-ton-per-day, 99.5-percent-purity oxygen plant (split-cycle), 450 p.s.i.g. discharge pressure........................ 6

2. Effect on selling price of return on investment, 99.5-percent-purity oxygen plant (split-cycle), 450 p.s.i.g. discharge pressure........................ 6

COST OF TONNAGE OXYGEN[1]

by

Sidney Katell[2] and John H. Faber[3]

SUMMARY AND CONCLUSIONS

Tonnage oxygen plants are or can be made available in sizes ranging from 150 to 1,000 tons per day. Capital requirements are estimated from \$5,400 to \$14,700 per daily ton, depending upon size of plant, cycle employed, and purity and discharge pressure of the product. Similarly, operating costs before return on investment will range from \$4.80 to \$10 per ton.

INTRODUCTION

Several processes[4 5] that can be used to convert coal to synthetic liquid fuels, synthetic pipeline gas, or hydrogen require high-purity oxygen as one of the basic raw materials. Depending on the end product and its specific use, the oxygen required will be of 95 or 99.5 percent purity. The quantity required, in turn, depends on the process for which the oxygen will be used and the size of the processing plant and will range from 150 to 4,000 tons per day.

Several tonnage oxygen plants have been built in the past few years for use in ammonia and steel plants. Some plants were purchased outright; others were built and operated for "over the fence" sale of the product. A recent article[6] mentions leasing of facilities and compares the costs of leasing with that of purchasing the equipment.

Another factor that enters into the complexity of an economic analysis of oxygen costs is the cycle used to give a product of a specific purity. Still

---

[1] Work on manuscript completed May 1959.

[2] Chief, Process Economics Evaluation Staff, Bureau of Mines, Morgantown, W. Va.

[3] Chemical engineer, Bureau of Mines, Morgantown, W. Va.

[4] Katell, Sidney, The Economic Outlook for Pipeline Gas From Coal: Coal Age, vol. 63, No. 9, September 1958, pp. 116-118.

[5] Katell, Sidney, Faber, John H., and Constantine, Marc T., The Economic Aspects of Production of Pipeline Gas Using Lurgi Generators for Gasifying Bituminous Char: Coal Age, vol. 64, No. 8, August 1959, pp. 92-95.

[6] Nachod, J. Ernest, How Leasing Conserves Capital: Chem. Eng., vol. 65, No. 12, June 16, 1958, pp. 150-153.

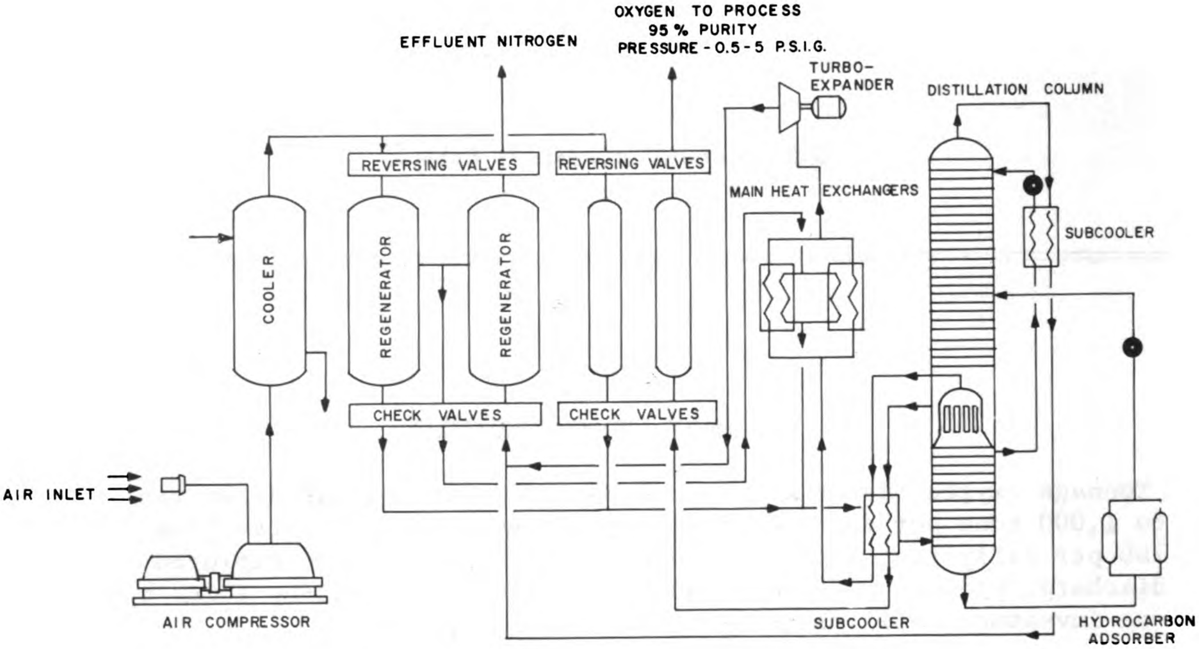

FIGURE 1. - Low-Pressure Cycle (Discharge Pressure, 0.5 to 5 p.s.i.g.).

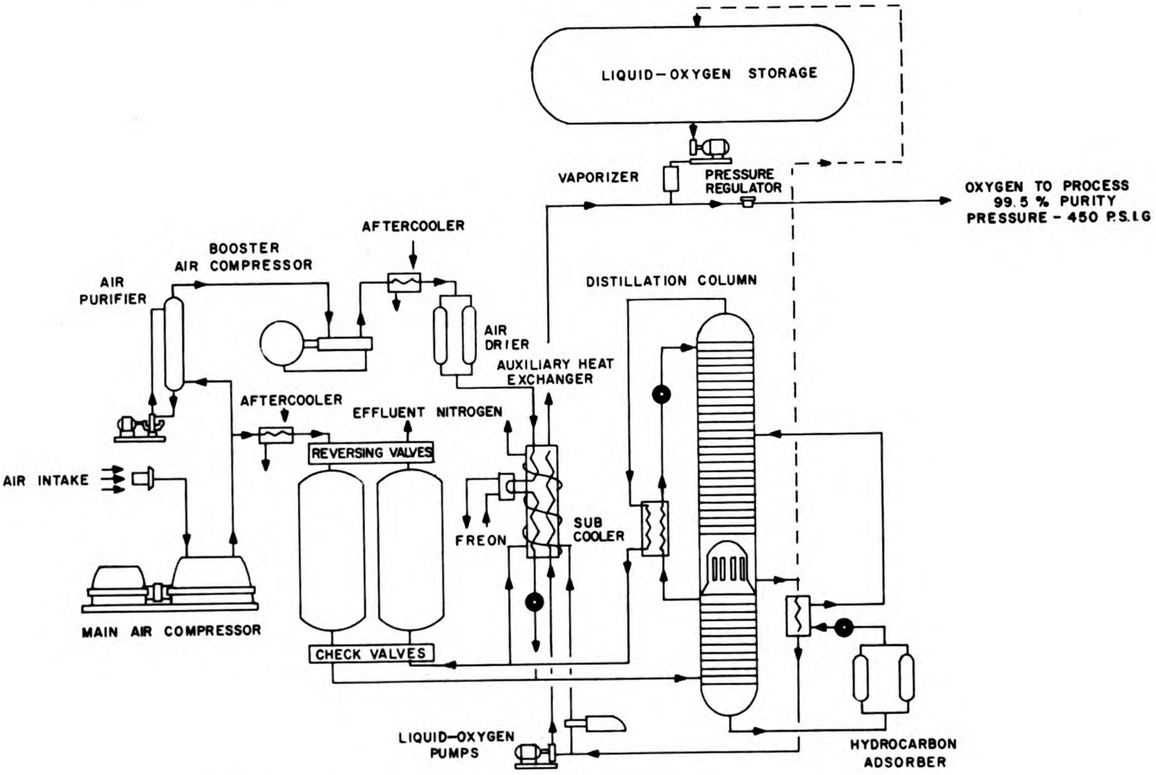

FIGURE 2. - Split Cycle (Discharge Pressure, 450 p.s.i.g.).

another factor is the discharge pressure at which the oxygen is required. As both factors will determine the power requirements, they must be clearly defined in any cost analysis.

Some investigators[7] point out that generalizations cannot be made regarding oxygen plants. Bearing this in mind, the following assumptions have been made for the specific cost analysis of this report:

1. Location of plant--Ohio Valley.
2. Size of plant--150 to 1,000 tons per day (larger requirements would be obtained by installing multiple units).
3. Purity--95 or 99.5 percent.
4. Pressure specifications--450 p.s.i.g. discharge.
5. Process employed--low-pressure[8] or split-cycle.[9] (See figs. 1 and 2.)
6. Cost of available power--$0.0075 per kw.-hr.

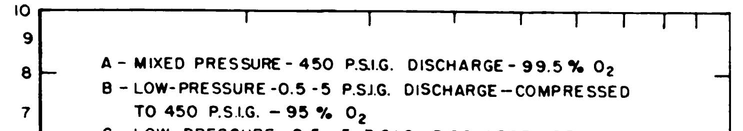

FIGURE 3. - Oxygen Plant; Capital Investment vs. Daily Production.

In the low-pressure process air is compressed to 85 p.s.i.g., and a gaseous product of 95 percent purity is produced at a discharge pressure of 0.05 to 5 p.s.i.g. The inlet-air feed in the split-cycle process is also compressed to 85 p.s.i.g. However, it then splits into two streams; 25 percent is further compressed to 1,500 p.s.i.g., then combined with the rest of the low-pressure stream before entering the distillation column. The 99.5-percent-pure gaseous product is delivered at pressure.

DISCUSSION OF RESULTS

Figure 3 shows the relationship between capital-investment requirements and plant capacity. Curve A was established for the split-cycle, air-fractionating process, which will deliver oxygen 99.5 percent

---

[7] Chemical Engineering, New Oxygen Route Vies for On-Site Honors: Vol. 65, No. 12, June 16, 1958, pp. 66, 68, 70.

[8] Van Dyke, H. Bingham, and Dougherty, J. W., Cost of Low-Temperature Processing: Chem. Eng. Prog., vol. 51, No. 4, April 1955, pp. 157-161.

[8] Work cited in footnote 7.

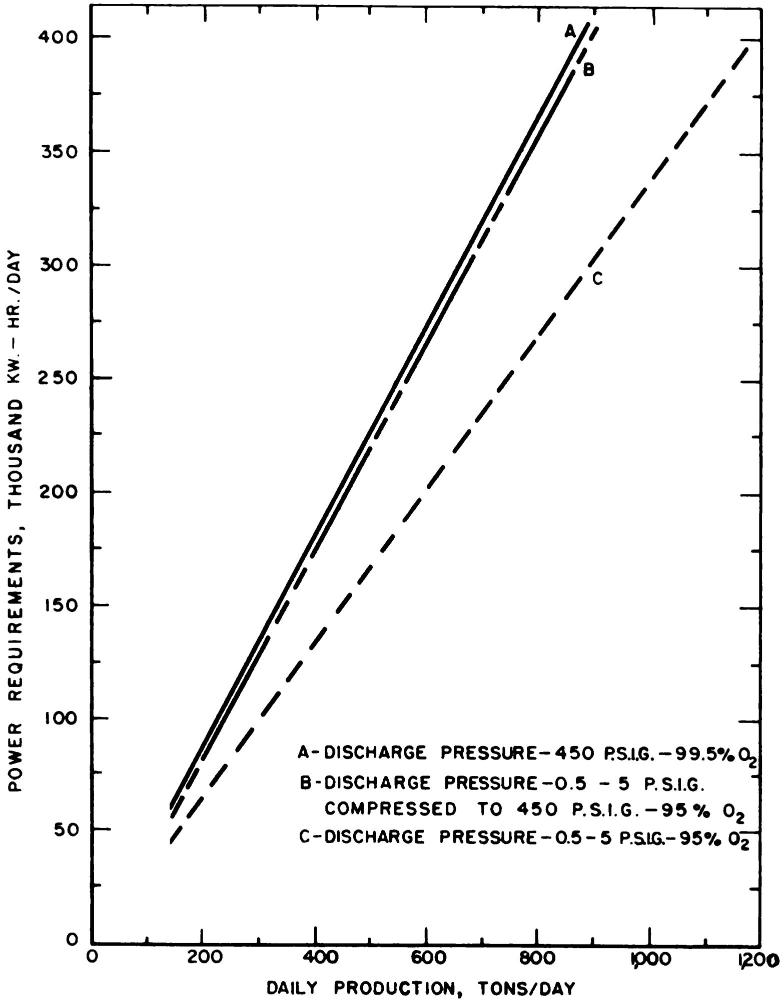

FIGURE 4. - Power Requirements for Tonnage Oxygen Plants; Daily Production vs. Power Requirements.

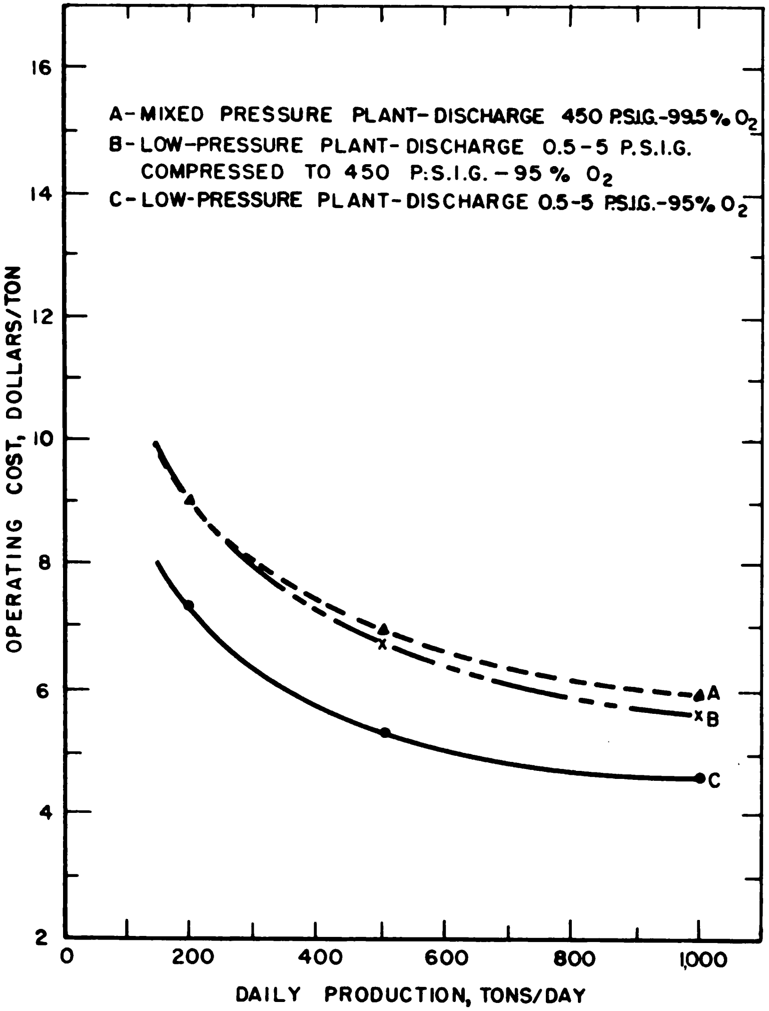

FIGURE 5. - Oxygen Plant; Operating Cost vs. Daily Production.

pure at a discharge pressure of 450 p.s.i.g. Capital costs for the low-pressure cycle plant, producing 95-percent oxygen at a pressure ranging from 0.5 to 5 p.s.i.g., are represented by curve C. Curve B shows the cost of compression to 450 p.s.i.g. for the low-pressure system. Figure 3 was developed from data provided by oxygen-plant vendors.

The manufacturer has claimed that the split-cycle system offers greater reliability because it can produce a small quantity (3 percent) of liquid oxygen that can be stored and used during emergency shutdown. The exponents of the low-pressure system state that with slight modification the system can produce a 99.5-percent-pure product. However, neither claim materially affects the economic aspects of this study.

Figure 4 shows the relationship between power requirements and plant capacity. As the low-pressure cycle produced oxygen at a discharge pressure of 0.5 to 5 p.s.i.g., it is necessary to include the additional power required to compress the gas to the common discharge pressure of 450 p.s.i.g.

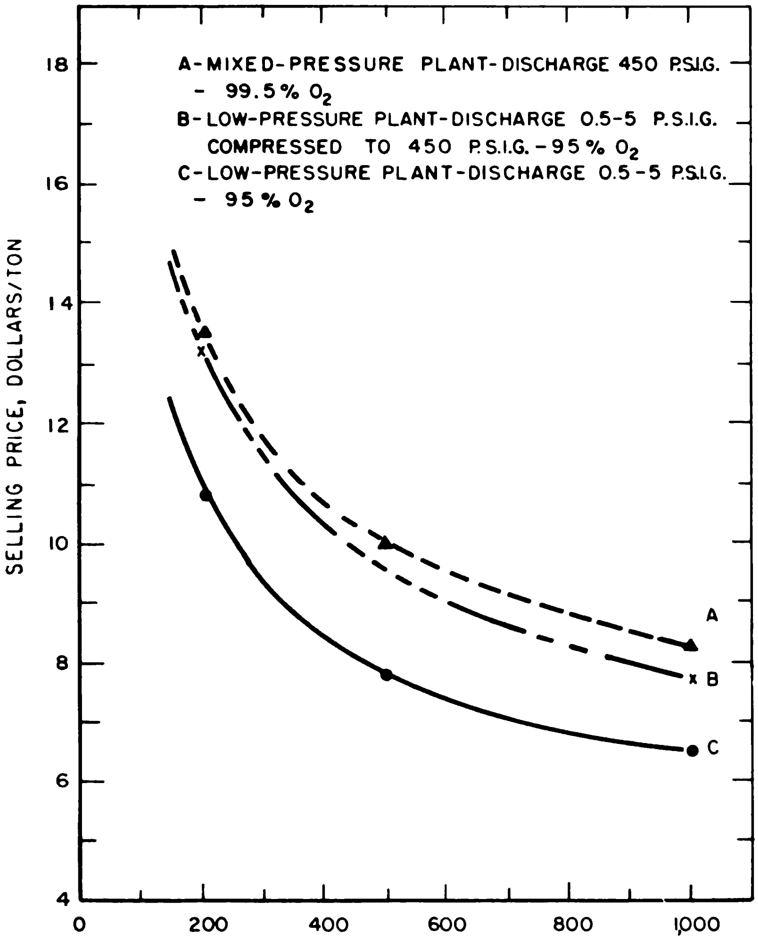

FIGURE 6. - Oxygen Plant; Selling Price vs. Daily Production (Return on Investment, 12 Percent.)

Operating costs were calculated for different-tonnage oxygen plants. The results are shown graphically in figure 5. The cost calculations assumed that power was available at $0.0075 per kilowatt-hour and labor at an average of $2.50 per hour. Plant maintenance was estimated at 1.5 percent of the total investment, payroll overhead at 18.5 percent of the total payroll, and taxes and insurance at 2 percent of the total investment. Depreciation was established on a straight-line basis at 6.66 percent per annum. The operating factor for the plant was taken as 96 percent, or 350 days of operation per year.

Figure 6 is similar to figure 5, except that a gross return of 12 percent on the investment has been included. Table 1 gives operating costs for a 500-ton-per-day plant. Table 2 shows the effect on the selling price of a variation in the return on the investment for one of the systems under investigation.

TABLE 1. - Estimated operating cost of 500-ton-per-day, 99.5-percent-purity oxygen plant (split-cycle), 450 p.s.i.g. discharge pressure

Capital investment, $4,450,000

Direct cost:		
Raw materials and utilities:		
Power--228,000 kw.per day x 350 x $0.0075 per kw.	$598,500	
Cooling H_2O--3,000 g.p.m. x 60 x 24 x 350 x $0.015 per thousand gallons per minute	22,700	
		$621,200
Direct labor:		
48 man-hours at $2.50 x 365	43,800	
Supervision at 15 percent	6,600	
		50,400
Plant maintenance (1.5 percent of investment)		66,800
Payroll overhead (18.5 percent of payroll)		17,500
Operating supplies		7,400
Total direct cost		763,300
Indirect cost: 50 percent of labor, maintenance, and supplies		62,300
Fixed cost:		
Taxes and insurance at 2 percent of investment		89,000
Depreciation at 6.66 percent		296,600
Total operating cost		1,211,200

Annual production = 500 tons per day x 350 = 175,000 tons per year.

Operating cost = $\frac{\$1,211,200}{175,000}$ = $6.92 per ton.

Selling price (with 12-percent return) = $6.92 + $3.05 = $9.97 per ton.

TABLE 2. - Effect on selling price of return on investment, 99.5-percent-purity oxygen plant (split-cycle), 450 p.s.i.g. discharge pressure

Size of plant, tons per day	Operating cost per ton	Selling price per ton 12-percent return	Selling price per ton 20-percent return	Selling price per ton 30-percent return
150	$10.00	$15.14	$18.57	$22.86
200	8.98	13.44	16.41	20.12
500	6.92	9.97	12.01	14.54
1,000	5.95	8.25	9.78	11.69

Another major factor is the cost of power. In the preceding tables the value of $0.0075 per kilowatt-hour was used in the calculations. Increasing the cost of power to $0.01 would add $1.14 per ton to both the operating costs and selling prices shown in table 2. Conversely, decreasing power costs to $0.005 would reduce both by $1.14 per ton of product.

U.S. GOVERNMENT PRINTING OFFICE : 1959 O—532777